Drinking Water Fountains with Reduced Number of Bacteria

Conceptual Design Report

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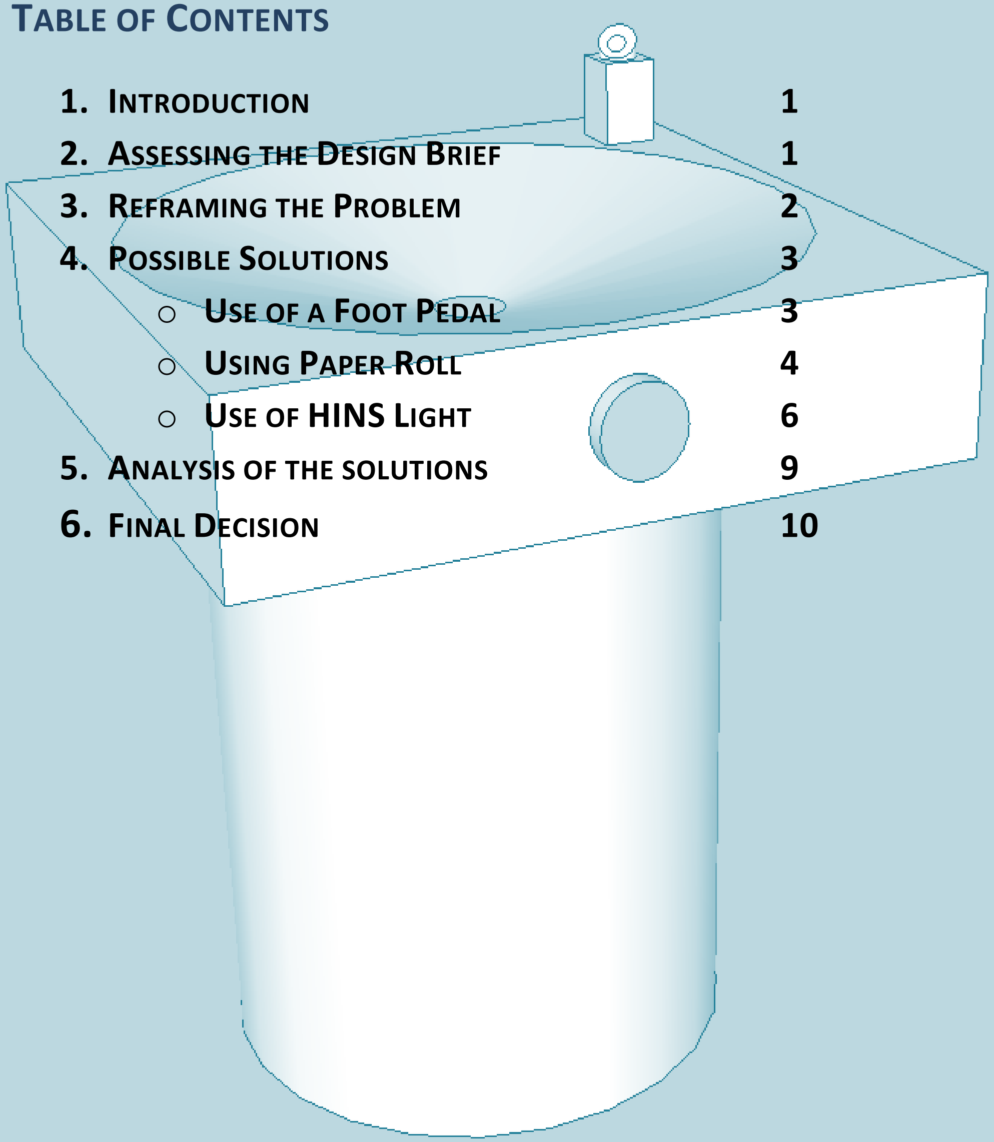

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Introduction

The design brief “Minimizing Germ Transfer from Contact with Bathroom Doors” raises the important problem of hygiene issues and illness that are caused as a result of micro bacterial transmitted via highly used surfaces. However, the design team’s approach to solving this issue seems to be a result of a lack of proper research. Therefore, this conceptual design report will first and foremost provide an assessment of the design brief. That will be followed by a discussion of the reframing of the problem keeping the objectives in mind. Next, it will thoroughly discuss three possible solutions that meet the constraints and can be used to minimize this issue. Lastly, the report will choose the best solution after weighing all three solutions against the criteria.

Assessing the Design Brief

The design brief provides an excellent premise for the need to minimize the amount of microbes that are transferred from person to person due to contact with highly touched surfaces and how that would improve personal efficiency. It does so by citing an article which states that in an experimentally conducted study it was found that individuals who sanitize and wash their hands frequently, miss 43% less school or work days as opposed to those who do not. The brief states that the transfer of infection can be reduced by redesigning highly touched surfaces and spreading awareness about the use of hand sanitizers. The design team proposes that the focus should be on redesigning washroom doors in order reduce the number of microbial germs that are transferred through contact with them, and this is the main objective of the brief.

However, there are four concerns because of which this objective needs reframing. First of all, the design group provides no evidence in order to support their claim that public washroom doors are highly used or have large number of bacteria on them. There is no explanation as to why bathroom doors have specifically been chosen over other surfaces for the given task. Additionally, the brief explicitly states that the new design should be a door. This means that any alternative method cannot be used and hence, restricts the creative space. Furthermore, two of the constraints state that the doors should provide for a visual and sound barrier. There is no reasoning or evidence provided as to why they are required to do so, and hence, the constraints seem to be baseless. Lastly, if washroom doors were a problem, then there already exist solutions to this problem. For instance, not having a door at all will be equally good as having a door which opens when it detects motion. These four issues call for readdressing the objective.

Reframing the Problem

The major objective of the brief is to ensure that there is lower number of bacteria transferred from one person to another through regularly used surfaces. Therefore, our design team decided to search for highly used surfaces. It turns out that drinking water fountain stations are one of the most frequently touched surfaces. [14] In a study published by National Sanitation Foundation, it was found that they have the highest number of bacteria on their surface, 2.7 million bacteria per square inch, which is thousands more than any public restrooms. [13, 16] In fact, toilets stood eighth on the list. [13] The damp and rarely disinfected surfaces of drinking fountains provide for perfect conditions for bacteria to grow and this makes them highly unsafe. [15]

A study conducted at Hairmyres Hospital, East Kilbridge, UK, investigated the effects of environmental cleaning on hospital-acquired infections.[11] Common hand-touched sites in hospital were illustrated to be continuously contaminated by pathogens.[11] By increasing efforts to remove the pathogens, infection rates for patients were successfully reduced. [11] This evidence illustrates the likelihood that by decreasing the number of bacteria on commonly touched surfaces, fewer pathogens were transferred to patients. Thus, by reducing the amount of bacteria on the water fountain button, fewer microorganisms will be transferred to users.

Subsequently, our design group has decided to propose a design for drinking water fountains that can successfully reduce or eliminate the number of bacteria that dwell on their surface. In addition to keeping the applicable constraints from the original brief, our design team has imposed some other relevant requirements. All of the constraints are listed below:

1. Should not take recognizably more user effort to operate.
2. Should be accessible for persons with disabilities and follow the standards listed in City of Toronto Accessibility Design Guidelines.
    - Clear knee space of 765mm wide x 735mm high x 250mm deep
    - The bowl should be between 760mm and 915mm high
3. Combining the product and installation, the cost must be under $5000.
4. Should be safe for the users (for instance, avoiding the use of chemicals, that can cause harm to human beings in order to kill the bacteria)

The criteria against which the new drinking fountain design will be judged have undergone minor amendments because of there being no change in the main objective. They are as following:

1. The percentage of reduced microbes transferred from the drinking water fountain to the user (greater is better)
2. Cost of product and installation (less is better)
3. Simplicity of manufacturing (an add-on to the existing system is preferred over a completely new design)
4. Should be convenient for as many stakeholders as possible; some stakeholders include:
    a. Water fountain users, mainly students and staff of the University of Toronto
    b. Drinking water fountain manufacturers
    c. Drinking water fountain distributers
5. Comfort level and intuitiveness of usage (greater the better)

Possible Solutions

In this section, three solutions will be proposed and their positive and negative aspects will be discussed after comparing them to the constraints and criteria. The first two solutions focus on completely avoiding contact with the water fountain button and the next one proposes improvements that can be made to the design of the button.

What about Motion Sensors?

At first glance, this problem seems very similar to the original problem. However, unlike a door, the use of a motion sensor is not a possible solution. The main problem with motion sensors is that they sense motion, not presence. The sensor would activate the fountain if someone were to walk up to it, but once they stop moving and start drinking, there is no more motion for the sensor to pick up on, so the fountain would turn off. Humans emit infrared light changing the infrared light of the surrounding area. Most sensors operate using passive infrared detection. This means they detect a rate of change of infrared light, not the change itself. So, the sensor would detect someone walking up to the fountain, but would not register them once they were standing in front of the fountain and no longer walking. If this is the case, the fountain would turn off. This is why we chose not to pursue a motion sensor as a solution to this problem.

Use of a Foot Pedal

Introduction One way to reduce transfer of bacteria on the highly contacted surface of the button on a water fountain is to eliminate the button altogether. This is made possible by the use of a foot pedal/force sensor. This apparatus consists of a spring loaded plate at floor level, connected to a spring loaded valve in the fountain via a metal rod (as shown in **Figure 1**).

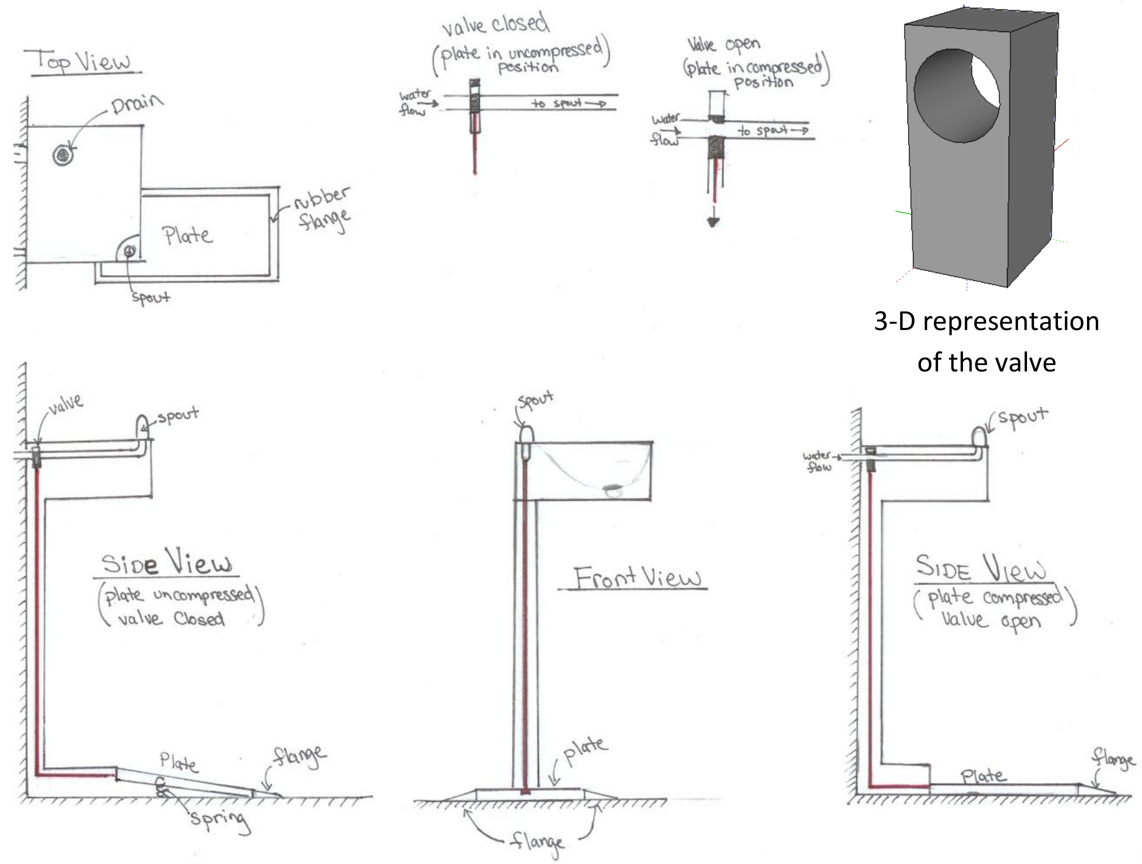

Figure 1: Different views of the Foot Paddle Design

Design When weight is applied to the spring loaded plate (by standing on it), it compresses, becoming level with the floor. This lowers the metal rod, pulling down on a spring loaded valve in the plumbing, opening it and letting the water and out the spout of the fountain.

The spring in the spring loaded plate should be just stiff enough to compress when a child (average mass of a 6 year old child is 25 kg) stands on it. [18] Since the spring in the spring-loaded plate should be just stiff enough to plate is essentially a ramp with a very small incline (about 2 cm), it is easily wheelchair accessible. There is a flexible rubber flange that goes all around the plate, easing the transition between it and the floor and allowing the plate to rise and lower without creating a gap between the plate and the floor.

Meeting the Constraints This solution meets the objective and abides by all the constraints (that could be reframed for water fountains) stated in the design brief:

1. The foot pedal is operated by standing on the plate, and compresses under the users body weight therefore it takes almost no 'recognizable' force. There is definitely no extra force required to operate the water fountain using the foot pedal.
2. The height of the bowl of the water fountain is only dependant on the length of the metal rod that connects the pedal to the valve, and the length of that rod doesn't depend on anything, so it could easily be made to fit the dimensional restrictions outlined in City of Toronto Accessibility Design Guidelines for Water Fountains.
3. The main problem with this solution is that it is costly, because of the many parts that need to be manufactured. Although at this stage in the design process it is uncertain what the exact cost would be, it is very likely that it would be near or possibly over the $5000 limit.
4. Because the design does not use any injurious chemicals or machineries in its design, it is quite safe. However, there is still the risk of people not noticing it on the floor and hence, stumbling over it.

Measuring the Criteria The solution does well when judged against the criteria:

1. By getting rid of the button, no contact is made with the bacterial filled surface of the water fountain, thus not only reducing the transfer of bacteria but eliminating it altogether.
2. As mentioned earlier, the cost will probably be high. However, once assembled, installation itself is not very difficult. All that is required to install this fountain is the plumbing for clean water and drainage (which would already be in place if there is an already existing fountain in that location), a flat floor and a flat wall, as every other component is already integrated into the new fountain.
3. Both in manufacturing and labour, it has numerous components that have to be individually manufactured and assembled, and implementation requires complete removal of existing fountains and installation of the new fountains. Therefore, the solution is not simple to produce.
4. As mentioned above, the design is not very suitable for stakeholders like manufactures and installers. However, as far as University students and staff are concerned, the solution successfully does its job.
5. The foot pedal is wheelchair accessible and the foot pedal is sensitive enough to allow the wheel of a wheelchair to activate the water fountain (minimum mass required to activate the water fountain is 25 kg, much less than 50 kg, which is half the average mass of an occupied wheelchair). [17]All the user needs to do is stand in front of the fountain, and hence it is comfortable and intuitive to use

Installing a Tissue Paper Roll

Introduction In order to fulfill the objective of decreasing the amount of bacteria transferred the avoidance of contact between the user and the button is an ideal solution. By placing a barrier between the user and the button, the avoidance of contact is achieved. This barrier must be effective at removing bacteria between one user and the next. Immediately, two different types of barriers come to mind. One method would be to have a reusable barrier that must remove bacteria after each use. The second method would have to be a disposable barrier after each use. By taking a quick look at the criteria and constraints, it can be seen that they are both safe, intuitively easy to operate and cost the same. The first method must contain an operation that disinfects or cleans the reusable barrier after each use to minimize bacteria transfer. However, the second simply disposes of the used barrier and ensure that the next would be touching a much cleaner surface. Since the primary objective is to reduce microbe transfer, the second method will be used. Since a disposable barrier is needed, paper was chosen as an appropriate material to be used as a barrier.

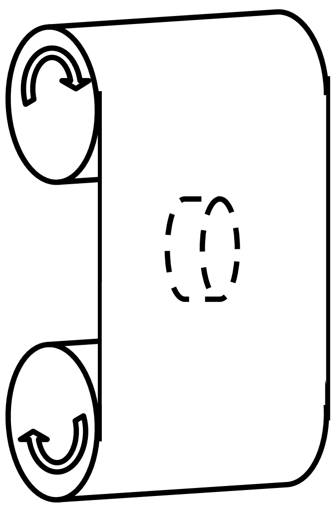

Figure 2: Paper acting as a Barrier to Prevent Contact between the User and the Button

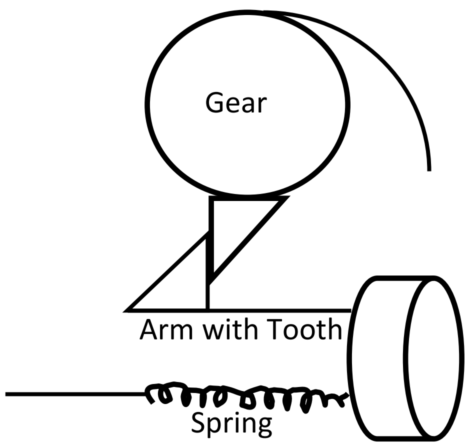

Figure 3: The Button with the Spring and Tooth that will turn the Gear and Roll of Paper

Design There would have to be two rolls: one at the top and one at the bottom (see figure 1). The top would contain unused paper and, after each use, the paper would be rolled into the bottom such that no two users will touch the same piece of paper. This uses the same concept as the paper that is used in a doctor's office to cover the bed. By preventing contact between the user and the button, by placing a barrier between the user and the highly-contacted surface, the amount of bacteria transferred is greatly reduced.

In order to prevent contact between surfaces and the user, it is ideal if the roller automatically rolls the paper after each use. Of course, it is possible to arrange for electrical solution. However, a mechanical design for an automatic design will be presented. First, there must be a gear that is attached to the one of the rolls. The button will be attached to a spring such that when it is pressed, it would spring back out afterwards. Attached to the button would be a triangular tooth that only catches the gear when springing back. See figure 2 for a picture of the design.

Meeting the Constraints The design completely satisfies all of the objectives and constraints outlined:

1. This design will not take more user effort to operate when compared to the original button. As this solution is merely an add-on to the original design of the water fountain. However, this is an added spring and depending on what type of spring is chosen, a slightly higher force might be required.
2. This new water fountain design will be the same as the previous design. Thus, the accessibility of the water fountain will be the same as the water fountain that preceded it.
3. Since the majority of changes that have to be added to the fountain would simply be an add-on to the existing fountain, the cost of installation would be inexpensive. However, this comes at a trade-off as the paper must constantly be replaced. This incurs an on-going cost that will eventually exceed $5000.
4. There is no hazard that is present for the users as the teeth would all be enclosed inside the fountain itself.

Measuring the Criteria

1. There will little to no microbes transferred as the users will all be contacting different surfaces. Similar to the use of paper covering the doctor's bed, there is little risk of transferring diseases from one person to the next.
2. As mentioned in part 3 of 'meeting the constraints', the initial cost would be fairly cheap. However due to the recurring cost of replacing paper will eventually surpass the initial cost of other solutions.

3. The solution should be a simple addition to the existing system. The gear, rolls of paper and button can be manufactured separately and then added on to existing water fountains.
4. The design satisfies the requirements of many of its stakeholders. There will be a need to add a slit in the water fountain to allow for the paper to come out and cover over the button. Once all the parts are manufactured, they can be easily assembled. As for the users of the water fountain, the basic design will be kept intact so the water fountain 'experience' is unchanged. Also, it would benefit them as they would not have to touch the germs that exist on the water fountain's button.
5. The design will be very intuitive to use. The process of pushing a button to activate the water fountain is still the same. However the button is hidden, it could be problematic in the beginning as users would be slightly confused. Since the process is still the same, the adoption of this design should be quick and easy.

Use of HINS Light

Introduction Conventional methods to minimize the amount of bacteria on a surface include but are not limited to applying ultraviolet (UV) light, household cleaners, or hygienic products. [1] No conventional method is ideal; UV light damages genetic information and cleaning products are not only environmentally wasteful by consuming resources, but may be hazardous to ones health. [3-4] The high level of safety, resource efficiency and ability to destroy microorganisms exemplify that high intensity narrow spectrum (HINS) technology is the superior decontamination method. [5-7] In this proposed solution, background information on UV light and HINS light are provided, HINS is claimed to be the superior decontaminating method, and the application of HINS light to destroy microorganism on the button of a water-fountain is discussed.

Background Information A conventional decontamination method incorporates the application of ultraviolet light to a surface, specifically within 200 to 300 nanometer wavelengths, as UV light inhibits the functionality of a microorganism. [2] Most importantly, it prevents microorganisms from being able to replicate and infect other organisms. [2] Ultraviolet light applied to a microorganism is absorbed by the RNA and DNA, initiating the production of bonds between adjacent nucleotides as light energy is converted into chemical. [2] Photochemical damage induced by UV light inhibits the functionality of DNA and RNA, disabling the bacteria from replicating and infecting living cells. [2] Once genetic damages surpasses excessive levels, the bacteria will no longer be able to function, and will shortly die. [2]

A team of research engineers at the University of Strathclyde in Glasgow were granted a patent in November 2009 for the use of high intensity narrow spectrum light as a decontamination method. [8] A light wavelength of 405nm was found to minimize microorganism survival rates. [8] HINS light "stimulates endogenous microbial porphyrin molecules to produce oxidising reactive oxygen species (ROS), predominantly singlet oxygen ($^1O_2$) that damages cells leading to microbial death." [6] Essentially, the light energy is absorbed by porphyrin molecules induces the production of lethal levels of ROS, provoking bacterial suicide. [6]

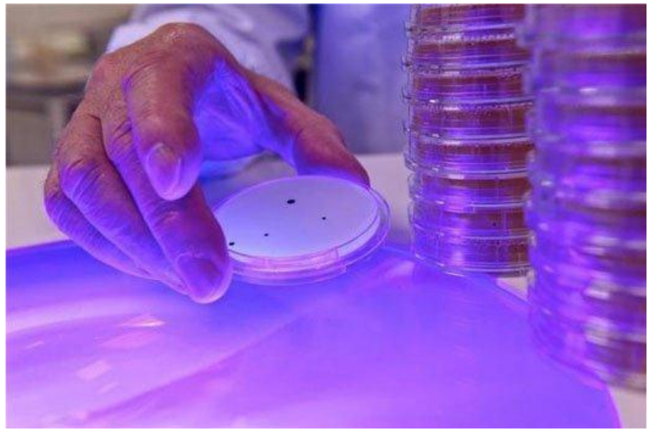

Figure 6: HINS light being applied to a petri dish. [9]

Comparison The superior decontamination method, a safe, environmentally friendly and efficient solution, involves the application of high intensity narrow spectrum light to a surface. Not only is HINS light effective towards antibiotic resistant microorganisms, a prominent capability of this technology, but the method is also harmless to humans. [9] A study performed by the developers of HINS light illustrates that light-emitting diodes (LED), the most cost-effective light source, can be used to produce HINS light. [6-7] The team performed another study in different hospital wards, testing the amount of microorganisms on a high-contact surface before, during, and after HINS treatment. On average, HINS light killed 60% of microorganisms. [5] The study also claimed that "all organisms (noteworthy microorganisms include escherichia coli, salmonella enteritidis, and clostridium difficile) tested to date have shown susceptibility to HINS-light." [10]

The benefits and minimal drawbacks of HINS relative to conventional decontamination methods illustrate its superiority as a decontamination method, prompting the design team to incorporate its use in this proposed solution. Constraints number four, which inhibits the use of 'harmful chemicals,' restricted the solution from consuming chemical disinfectants such as borax. Furthermore, the environmentally destructive consumption of sources used to produce cleaning agents, which are potentially hazardous to humans, encouraged the design team to rule out solutions that consume resources. [4] UV treatment poses advantages over chemical disinfectant methods as it avoids the continuous consumption of resources (i.e, plastic is produced for the disinfecting agents, fuel is used to transport the chemical cleaner), except for electricity which can be generated by environmentally friendly methods. The drawback of ultraviolet light treatment is that the light exhibits the same affects to humans as it does to microorganisms, it stimulates genetic damage.[3] The carcinogenic nature of ultraviolet light promoted the design team to instead incorporate HINS light into this design, a human-safe method that avoids non-environmentally friendly resource consumption.

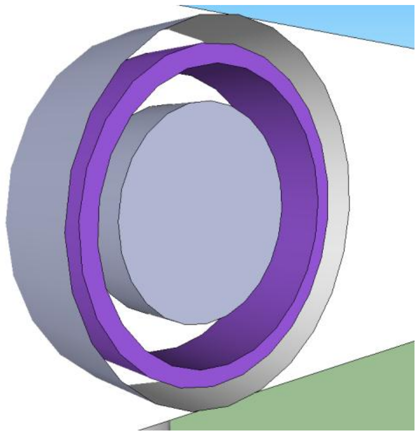

Figure 4: HINS Light can only be emitted through the inside of the dome

Design Shinning HINS light directly on the on/off control of a water-fountain minimizes the amount of bacteria transferred to users by decreasing the initial amount of bacteria on the water fountain. The addition of an open dome shaped structure (**figure 7 and 8**), surrounding the water fountain button, that completely encloses the lighting system will provide protection against weathering and physical damage to the light source. The dome is meant to minimize the probability of damage to the lighting system. By constructing the inside of the dome from a translucent or transparent material, HINS light will be able to shine on the button. HINS light escaping through the outside of the dome indicates inefficiency of directing light towards the button and is irritating to the public. Thus, the light must be contained within the boundary. Lastly, the boundary adds an aesthetic appeal to the water fountain as it will illuminate the button.

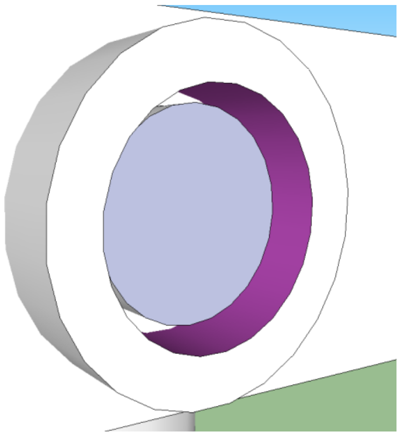

Figure 5: Top and inside of dome removed. The purple cylinder illustrates the HINS source

Meeting the Constraints Using HINS light to reduce the amount of bacteria on a water fountain button successfully achieves objectives one, two and four. It pushes back against objective number 3:

1. The addition of an HINS light source to a water fountain requires minimal increase efforts from the users to activate the water fountain, it limits an individuals accessibility to the on/off control to a horizontal direction.
2. The addition of an HINS light source does not generate accessibility issues as described by the City of Toronto Accessibility Design Guidelines.
3. The installation of an HINS light source and a boundary would be of a minimal cost. The total cost would increase as electricity is consumed, eventually surpassing the $5000 limit.
4. HINS is not harmful to humans, and the light source is contained, successfully preventing electrocutions.

Measuring the Criteria Although HINS light successfully attained the objectives, the solution performs well against all criteria except for number two and five:

1. HINS light successfully reduces the amount of microbes transferred from the water fountain button to the user.
2. Although the initial cost would be inexpensive, long-term costs will greatly exceed ideal the objective limit of $5000.
3. This system can be added onto an existing system without having to modify the initial water fountain. It can also be incorporated into water fountain during manufacturing.
4. As the HINS method successfully reduces the amount of bacteria on a water fountain button and can be added onto an existing system, it appeals to all stakeholders.
5. Although the existing comfort level would be hindered by this solution due to its necessary restriction of accessibility to the button, a users intuition of how to active the water fountain would be enhanced. The illuminating glow produced by the HINS light would attract the attention of the user, allowing them to identify the location of activation controls for the water fountain.

ANALYSIS OF THE SOLUTIONS

In order to appropriately and methodically select the best option, first of all, all of the four solutions were weighed against all the constraints and criteria using the Pugh's Selection Procedure. The Foot Pedal was arbitrarily chosen to be the standard against which all of the other solutions were weighed. The process has been depicted in the following table.

SOLUTIONS / CRITERIA	Foot Pedal	HINS Light	Tissue Paper
Safety	S	S	+
Cost	S	-	-
Percentage of Reduced Germs	S	-	S
Simplicity of Producing	S	-	-
Accessibility	S	+	+
Amount of User Effort	S	+	+
Sum of +	0	2	3
Sum of S	6	1	1
Sum of -	0	3	2

From the table, it is evident that the solutions which improvise a Foot Pedal and a tissue paper are better than the other one. They both perform relatively equally with Pugh's Selection Model. Hence, they were re-analysed using Weighed Decision Matrix, where each of the individual criteria were given specific weights and the solutions were assigned a score between 0 and 11; 0 for not meeting the criteria at all and 11 for completely satisfying the criteria. The product of the score and the weight was taken as the rating of the solution. This procedure has been shown in the following table.

CRITERIA	WEIGHT	SOLUTIONS	
		Foot Pedal	Tissue Paper
Safety	0.2	9	10
Cost	0.15	9	8
Percentage of Reduced Germs	0.3	11	11
Simplicity of Producing	0.1	7	7
Accessibility	0.1	7	11
Amount of User Effort	0.15	8	10
TOTAL	-	9.05	9.8

Final Decision

After weighing all three solutions against the main objective, the constraints and the criteria, it is evident that the solution that proposes the use of a paper roll is the best one. In summary, this solution is essentially an add-on the existing drinking water fountains and a completely mechanical process and therefore, will be inexpensive and easy to manufacture and install. Although, there will be an ongoing cost of paper rolls, that cost is negligible and is worthwhile if it can greatly reduced the infectious illnesses caused due to bacterial transfer. The design will also be intuitive to use because it only involves pressing a button; the drinking water fountains designed with this mechanism can also be made so that they are completely accessible by people with disabilities. It does not involve usage of any harmful chemicals or sharp machineries that can possibly cause harm to its users. Thus, this solution surpasses the other two.

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